TITLE

POWER DISSIPATION MANAGEMENT SYSTEM

RELATED APPLICATION

5   This application is claiming the benefit, under 35 U.S.C. §119(e), of the

provisional application filed November 20, 2002, under 35 U.S.C. §111(b), which was

granted Serial No. 60/427,812, and is hereby incorporated by reference.

FIELD OF THE INVENTION

10   The present invention relates to a power dissipation management system for

vehicles having one or more braking devices.

BACKGROUND OF THE INVENTION

Various braking systems designed to dissipate the kinetic energy of a vehicle are

15   known. One such system is described in U.S. Patent No. 5,184,875 which provides for

an electronically controlled braking system. A control unit receives a braking signal from

the driver. The unit selects one or more brakes of the vehicle to obtain deceleration

proportional to the braking signal. The vehicle has a friction service brake and a wear-

free auxiliary brake such as a fluid brake, an eddy current brake or a motor brake.

20   Preferably, the wear-free brake is triggered and, if the braking signal is significant

enough, the friction-affected brake is triggered. The system has signal transducers to

detect the condition (temperature, thickness, frequency of use) of the friction-affected

brake and the vehicle speed. If the system detects a condition in the brakes which has

lowered their coefficient of friction, the service brake is triggered exclusively to correct

the condition. If, however, the system determines that additional use of the service

brakes may overheat them, it triggers the auxiliary brake additionally or exclusively.

U.S. Patent No. 5,303,986 provides for a braking system having both an

5   electronic pneumatic braking system and a retarder which applies a retarding torque to

the vehicle driveline. The invention relates to integrating a retarder control system with a

control system for the pneumatically actuated brakes to distribute the braking required

between the systems without jeopardizing the braking balance between the driven and

non-driven wheels. A controller receives a braking signal from the vehicle operator,

10   from an engine or exhaust brake, or from the operator controlled retarder switches, in

addition to a signal from a vehicle load sensor. The controller also receives data from

sensors on each wheel regarding the speed of each wheel. The controller generates

output signals to the retarder, and the engine and/or exhaust brake. During normal

operation, the retarder is switched on, either manually or automatically, every time a

15   brake application is effected. The braking signal to the drive wheels is adjusted for the

effects of the retarders so that the braking balance front to rear is maintained.

U.S. Patent No. 5,441,335 provides for an electronically controlled motor vehicle

brake. An electrical braking valve pick-up generates an electrical output signal (U) as a

function of the actuation path of the brake pedal and is connected to an electronic control

20   unit. A gradient, $\Delta U/\Delta t$, which represents a measure of the actuation rate of the braking

value pick-up, is determined by the control unit from the variation with time of the output

signal. If the gradient is above a limiting value, the unit recognizes rapid braking. The

friction brake is engaged earlier and the auxiliary brake (e.g., engine brake, retarder,

constant throttles) may not ever be engaged. If the gradient is below a minimum value, slow braking is present. The friction brake responds relatively late so that the slower auxiliary brake can respond first and absorb most or all of the braking need.

U.S. Patent No. 5,613,743 provides for a method of controlling the slippage of driven wheels in a motor vehicle. Initially, a target braking torque for each of the respective driven wheels is determined. The torques are compared and the smallest of them is selected. A target engine torque is then determined from the smallest braking torque. The engine torque is adjusted to conform to the target engine torque. A residual braking torque for each wheel is calculated based upon the target engine torque and the respective target brake torques. The brake pressure at the driven wheels is varied so that the residual braking torques for each wheel are realized.

U.S. Patent No. 5,657,838 provides for a method of operating a drive unit for a vehicle having an engine braking system. The unit has an engine, a gearbox and a retarder in a constant drive connection with the engine. The unit also has a cooling circuit where the coolant is the fluid for the retarder. The retarder acts as a pump for the cooling circuit. An overall braking output is measured and compared to a value. When the overall braking output is less than the value, the retarder is activated to deliver the required amount. When the braking output is more than the value, the engine braking system is activated along with the retarder. The retarder delivers the difference in braking between that provided by the engine braking system and required amount.

U.S. Patent No. 5,816,665 provides for a retarder system for a drive train where the system is driven by a multi-cylinder engine via a transmission. The system has a compression brake adapted to operate in multiple stages to provide various degrees of

braking to the engine. A fluid retarder, also adapted to operate in multiple stages to absorb power from the engine, is coupled for rotation with the vehicular drive train. Each stage of the retarder corresponds to a specific braking level output from the retarder. For example, stage one provides only a small amount of fluid to circulate within the retarder

5   housing thus resulting in a small braking effect. Stage three, however, adds a predetermined amount of fluid to the retarder housing thus providing a larger braking effect. A controller is electrically connected to the compression brake and the fluid retarder to control them both to slow the speed of the vehicle.

U.S. Patent No. 6,287,237 provides for a method of controlling a drive train

10   including the steps of converting a braking signal from a brake petal into a braking torque. A setpoint value for an engine drag torque is determined based upon the braking torque. A downshift characteristic diagram is provided to determine a setpoint transmission ratio. The ratio is a function of the setpoint value for the engine drag torque and also of a variable functionally associated with the speed of the vehicle. The diagram

15   has characteristic curves defined by taking into account a minimum engine torque. Lastly, a transmission ratio is automatically set by reference to the diagram.

The present invention has the advantage over the prior art by distributing the kinetic energy of the vehicle among various components of the hydrodynamic transmission based upon the actual thermal capacity of the component. Distributing the

20   kinetic energy among the components of the transmission allows the size of the service brakes to be reduced and hence lowers their cost.

SUMMARY OF THE INVENTION

The present invention is directed toward a method and apparatus for a power

dissipation management system for vehicles wherein the thermal condition for a plurality

of driveline components is determined. Based upon the thermal condition of each

5   driveline component, a quantity of energy each can accept is determined. A braking

signal is provided to one or more of the driveline components based at least in part upon

the quantity of energy the component can accept.

BRIEF DESCRIPTION OF THE DRAWINGS

10   The above, as well as other advantages of the present invention, will become

readily apparent to those skilled in the art from the following detailed description when

considered in the light of the accompanying drawings in which:

Fig. 1 is a schematic of an embodiment of the present invention;

Fig. 1a is a schematic of another embodiment of the present invention;

15   Fig. 2 is a schematic of a component of the invention depicted in Figs. 1 and 1a;

Fig. 3 is a flow chart depicting a step sequence of the present invention;

Fig. 4 is a chart of torque against engine speed; and

Fig. 5 is a chart of turbine torque against turbine speed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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It is to be understood that the invention may assume various alternative

orientations and step sequences, except where expressly specified to the contrary. It is

also to be understood that the specific devices and processes illustrated in the attached

drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions, directions or other physical characteristics relating to the embodiments disclosed are not to be considered as limiting, unless the claims expressly state otherwise.

5   Fig. 1 schematically represents a portion of a power dissipation management system 10 for a vehicle (not shown). The system 10 comprises a plurality of driveline components 12 comprising a torque converter 14, at least one forward clutch 16, at least one reverse clutch 18 and at least one service brake 20. Although the following will describe the invention in terms of a single forward and a single reverse clutch, those

10   skilled in the art will readily appreciate that the present invention incorporates vehicles having more than one forward clutch and/or more than one reverse clutch or more than one clutching mechanism.

As known to those skilled in the art, coolant fluid, such as oil, is provided from at least one reservoir (not shown) through at least one fluid line 21a, 21b, 21c, and 21d to

15   each of the components 14, 16, 18, and 20, respectively. In one embodiment, a thermal sensor is operatively connected to each fluid line for each component as shown in Fig. 1. Thus, the torque converter 14 has a thermal sensor 22, the forward clutch 16 has thermal sensor 24, the reverse clutch 18 has a thermal sensor 26, and the service brake 20 has a thermal sensor 28. The thermal sensors 22, 24, 26, 28 sense the temperature of the fluid

20   entering each component 14, 16, 18, and 20, respectively. Each thermal sensor 22, 24, 26, 28 is connected to a computer 30 to provide the computer 30 with each sensed temperature.

In another embodiment schematically depicted in Fig. 1a, the coolant fluid is

provided from a single reservoir R through coolant lines L to the components 14, 16, 18

and 20. In this embodiment, only a single sensor S senses the temperature of the entering

coolant fluid. Sensor S provides the computer 30 with the sensed temperature.

5   As schematically depicted in Fig. 2, the computer 30 is comprised of a plurality of

modules including a driver intention module 32, an engine control module 34, a thermal

module 36, a clutch control module 38 and a braking module 40. Preferably, each of the

above modules 32, 34, 36, 38 and 40 are connected to a driving module 42.

The term module is used to describe functions of the computer 30, as will be

10   discussed in detail below. The modules 32, 34, 36, 38, 40, 42 may be combined with one

another in any combination, or they may exist individually, as depicted in Fig. 2.

Alternatively, the modules 32, 34, 36, 38, 40, 42 may be physically combined in a single

computer 30. Regardless of the embodiment, the computer 30 can execute one or more

of the modules 32, 34, 36, 38, 40, 42 in any order or sequence, including simultaneously.

15   As schematically depicted in Fig. 2, the driver intention module 32 is connected

to a sensor 44 on an accelerator pedal 46, a sensor 48 on a brake pedal 50 and it may also

be connected to one or more sensors 52 on hydraulic controls 54 for the vehicle. The

hydraulic controls 54 may be used for auxiliary vehicle hydraulic systems (not shown) as

known to those skilled in the art. The desired acceleration $V_{out,}$ based upon the sensed

20   position of the accelerator pedal 46, or the desired deceleration $B_{i,}$ based upon the sensed

position of the brake pedal 50, is received by the driver intention module 32 and sent to

the driving module 42. The sensed position of the hydraulic controls 54 may be similarly

received and sent.

The driver intention module 32 also comprises a speed sensor 55 for measuring the speed of the vehicle V_M. V_M is sent to driving module 42.

The engine control module 34 measures the actual revolutions per minute of the engine in any manner known to those skilled in the art. The measured engine speed is

5 transferred from the engine control module 34 to the driving module 42.

In a preferred embodiment, the clutch control module 38 is connected to at least one sensor 58 for sensing a forward clutch torque M_F of the forward clutch 16, at least one sensor 62 for sensing a reverse clutch torque M_R of the reverse clutch 18, and at least one sensor 66 for sensing a service brake torque M_{AB} of the service brake 20. Each of

10 these sensors 58, 62, 66 communicates some or all of the torques M_F, M_R, M_{AB} to the clutch control module 38 which in turn communicates them to the driving module 42.

If, for any reason, some or all of the torques M_F, M_R, M_{AB} cannot be sensed, the torque M_F, M_R, and/or M_{AB} is assumed to be equal to the desired clutch torque for that component. The desired clutch torque is determined by the braking module 40 and

15 provided to modules 38 and 42. The desired clutch torque is proportional to the amount of braking desired.

In the process of using the present invention, the sensed position of the brake pedal 50, the sensed position of the accelerator pedal 46 and the sensed positions of the vehicle hydraulic controls 54 (if any) are provided to the driver intention module 32. The

20 driver intention module 32 determines the desired acceleration V_{out}, the desired deceleration B_i and/or the desired engine speed (throttle) of the vehicle based upon the respectively sensed positions stated above. The desired acceleration V_{out}, the desired deceleration B_i, the desired engine speed of the vehicle (throttle) and/or V_M are sent to the

driving module 42 from the driver intention module 32. The driving module 42 signals

the engine control module 34 of the desired engine speed through a throttle signal and the

engine control module 34 maintains the engine at that speed.

By way of a first example, if the sensor 44 on the accelerator pedal 46 determines

5   the accelerator pedal 46 is being deflected, the vehicle operator likely wants the vehicle

to accelerate. In that case, the driver intention module 32 signals the driving module 42

that no braking through the driveline components 12, as described in more detail below,

is requested.

By way of a second example, if the sensors 52 on the vehicle hydraulic controls

10   54 senses that the controls 54 have been engaged, the driver likely wants to use the

auxiliary systems on the vehicle. In that case, the driver intention module 32 signals the

driving module 42 that no braking through the driveline components 12, as described

below, is requested.

The thermal module 36 uses a plurality of inputs to calculate a forward clutch

15   temperature T_F, a reverse clutch temperature T_R, a service brake temperature T_{AB}, and/or

a torque converter temperature T_{TC}. The inputs are provided from the driving module 42

and preferably comprise a power dissipated in the forward clutch P_F, a power dissipated

in the reverse clutch P_R, a power dissipated in the torque converter P_{TC}, and a power

dissipated in the service brake P_{AB}.

20   The power dissipated values P_F, P_R, and P_{AB} are calculated from V_M, the gear

ratios of the vehicle transmission, the engine speed and the clutch torques M_F, M_R, and

M_{AB}, respectively. As known to those skilled in the art, the gear ratios of the vehicle

transmission vary from transmission to transmission. Preferably, information on the gear

ratio for a particular transmission is provided to the driving module 42 as a configuration file. Those skilled in the art know that for each power dissipation calculation for each clutch, the power dissipated is the product of the speed difference over that clutch and the torque flowing through that clutch.

5   A power dissipated in the torque convert P_{TC} is calculated from V_M, the gear ratios of the vehicle transmission, the engine speed and the characteristics of the torque converter. Those skilled in the art know that the power dissipated is determined from standard tables using the engine speed and the turbine speed.

The inputs also include the entering coolant fluid temperature as determined

10   from the thermal sensors 22, 24, 26 and 28 for each respective component or thermal sensor S. Each temperature T_F, T_R, T_{AB}, and T_{TC} is calculated using the respective sensed cooling fluid entering temperature, or the cooling fluid entering temperature from sensor S, and by knowing the thermal properties of each component 14, 16, 18 and 20. Those skilled in the art know that the thermal properties of the components 14, 16, 18 and 20

15   comprise the thermal mass of the component, the coolant flow through the component, the amount of heat dissipated in the component and the geometry of the component.

In an alternative embodiment to that describe above, those skilled in the art will readily appreciate that the temperature of each component T_F, T_R, T_{AB}, and T_{TC} can be directly measured from the respective component.

20   Regardless of which of the above methods is used to determine T_F, T_R, T_{AB}, and T_{TC}, preferably, each of these temperatures T_F, T_R, T_{AB}, T_{TC} are communicated to the driving module 42.

As depicted in Figs. 2 and 3, the braking module 40 receives as inputs the forward

clutch temperature T_F, the reverse clutch temperature T_R, the service brake temperature

T_{AB}, the torque converter temperature T_{TC}, the desired acceleration V_{out} and the

deceleration value B_i. The braking module 40 determines the amount of energy the

5   forward clutch 16, the reverse clutch 18, the service brake 20 and the torque converter 14

can safely accept based upon the above inputs. The braking module 40 then compares

the amount of energy each of the above components 14, 16, 18, 20 can accept with a

plurality of braking profiles 64. The braking profiles are depicted as N, N+1,. . . N+. . .

in Fig. 3. If the amount of energy available in any of the above components 14, 16, 18,

10   20 is less than the braking energy called for in a braking profile 78 for any component 14,

16, 18, 20 then another braking profile 64 is selected. The amount of energy called for in

a braking profile 64 for the forward clutch is B_F, for the reverse clutch is B_R, for the

torque converter is B_{TC} and for the service brake is B_{AB}. The braking profiles 64 are

provided to the braking module 40 in order of highest braking efficiency for the vehicle

15   to lowest braking efficiency.

A braking profile 64 is selected that does not require more than, or is at least

equal to, the braking energy that the forward clutch 16, the reverse clutch 18, the service

brake 20 and/or the torque converter 14 can accept. It is within the scope of the present

invention that some profiles do not require braking on each drivetrain component.

20   The selected braking profile 64 converts the forward clutch temperature T_F, the

reverse clutch temperature T_R, the service brake temperature T_{AB}, the torque converter

temperature T_{TC}, the desired acceleration V_{out} and the deceleration B_i value into one or

more of the following: a forward clutch torque M_F, a reverse clutch torque M_R, a service

brake torque M_{AB} and/or a throttle setting (throttle).

Some or all of the torques M_F, M_R, M_{AB} are communicated to the clutch control

module 38 where they are converted to one or more of a forward clutch fluid pressure, a

5   reverse clutch fluid pressure, a torque converter pressure and/or a service brake pressure.

The pressures are communicated to their respective components in a manner known to

those skilled in the art. Similarly, the throttle setting (throttle) is communicated to the

engine control module 34 where it is converted to a torque converter pressure to the

torque converter.

10   The following braking profiles are provided in no particular order of preference,

but are provided as examples of preferred embodiments of the present invention. A first

braking profile has no thermal limitations, however, the engine must be operating at a

minimum revolutions per minute, often the idle speed of the motor. In this profile, the

engine is used to brake the driveline by decreasing the throttle. The engine speed

15   decreases and the torque converter 14 provides torque to the driveline in the opposite

direction of its rotation to slow the vehicle as known to those skilled in the art. The

maximum braking torque depends in part upon the engine speed and is higher for the

higher engine speeds of the vehicle as shown in Fig. 4.

A second braking profile decreases the engine speed, as provided above, to

20   engage the torque converter 14 as a brake on the driveline. The operator may prevent the

engine speed from decreasing beyond a set point to keep engine driven components

provided with sufficient power. Initially, fluid pressure is increased to the reverse clutch

18 while the forward clutch 16 is kept under full pressure. The reverse clutch 18 slips

and transfers torque through the forward clutch 16, thus braking the driveline.

As known to those skilled in the art, once the engine drops below a certain limit

determined by the engine speed, the torque converter 14 will begin to drive the driveline.

5   At that moment, the forward clutch 16 is completely opened, thus preventing the torque

converter 14 from providing energy to the driveline. The reverse clutch 18 continues to

absorb energy from the driveline, thus slowing it down further.

A third braking profile increases fluid pressure to just the reverse clutch 18 or

both the reverse clutch 18 and the forward clutch 16 in any proportion. For example, the

10   desired braking may be 100% in the reverse clutch 18, 80% in the reverse clutch 18 and

20% in the forward clutch 16, 50% in the reverse clutch 18 and 50% in the forward clutch

16 or 20% in the reverse clutch 18 and 80% in the forward clutch 16. Naturally, other

proportions of reverse 18 and forward clutch 16 braking are well within the scope of the

present invention.

15   Under this third braking profile, the torque converter 14 can be put into at least

three different modes by closed loop controlling the throttle and the torque flow through

the clutches 16, 18 or in an open loop system as known by those skilled in the art. The

three modes of the torque converter 14 include (a) counter rotation mode, (b) normal

mode, and (c) braking mode. These three modes are graphically depicted in Fig. 5.

20   As seen in Fig. 5, during counter rotation mode the turbine torque is high and the

turbine speed is low and slightly negative, thus the torque converter 14 is taking away

energy from the drivetrain and helping in braking. In this mode, those skilled in the art

will appreciate that the forward clutch 16 is stressed much more than the reverse clutch 18 to assist in braking.

In normal mode, there are two zones b1 (high turbine torque and low turbine speed) and b2 (low turbine torque and high turbine speed) that can be used for driveline

5   braking. However, other than these two zones it is preferred that this mode is avoided. In these zones, both the reverse 18 and forward clutches 16 can be slipped in various proportions as mentioned above.

In zone b1, the differential speed of the forward clutch 16 and the reverse clutch 18 are more or less equal. Thus, the forward clutch 16 is stressed more or less equally as

10   the reverse clutch 18.

In zone b2, the differential speed of the forward clutch 16 is low and the differential speed of the reverse clutch 18 is high. Thus, the reverse clutch 18 is stressed more than the forward clutch 16 to assist in braking.

In the braking mode, also depicted in Fig. 5, the turbine torque is low and

15   negative and the turbine speed is high. The differential speed of the forward clutch 16 is low, but the differential speed of the reverse clutch 18 is high. Thus, the reverse clutch 18 is stressed much more than the forward clutch 16 to assist in braking.

Entering into any of the above-described modes depends upon the amount of energy the forward 16 and the reverse 18 clutches can accept. When the reverse clutch

20   18 cannot accept additional energy, the energy is stored in the forward clutch 16 and vice versa. If neither clutch 16, 18 can accept any additional energy, the braking module will move to the next braking profile.

A fourth braking profile can be used if neither the forward 16 or the reverse 18 clutches can accept any additional energy or the amount of braking the forward 16 and/or the reverse 18 clutches can accept is not sufficient. In this braking profile, the service brakes 20 are engaged to provide the additional amount of braking required.

5   In accordance with the provisions of the patent statutes, the present invention has been described in what is considered to represent its preferred embodiments. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope.

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